

ULTRASONIC TRANSDUCER WITH A FLANGE FOR MOUNTING ON AN ULTRASONIC
WELDING DEVICE, IN PARTICULAR ON A WIRE BONDER

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BACKGROUND OF THE INVENTION

The invention is related to an ultrasonic transducer with a flange of the type named in claim 1.

Such ultrasonic transducers are used for all types of ultrasonic welding devices, for example wire bonders. Ultrasonic transducers of the type named in the preamble of claim 1 are known from the patent documents US 5 603 445, US 5 595 328 and US 5 364 005. To mount the ultrasonic transducer on the ultrasonic welding device, a flange is provided which is attached in a so-called longitudinal node of the longitudinal standing ultrasonic waves excited in the horn of the ultrasonic transducer. As however, antinodes from radial oscillations occur in a node of the longitudinal ultrasonic waves, the flange is only connected to the horn by means of webs in order to prevent as far as possible the transmission of ultrasonic energy from the horn to the flange and on to the ultrasonic welding device. From the energetics point of view, the transmission of ultrasonic energy could be quite acceptable. Much graver disadvantages can however be seen in that the electrical impedance of the ultrasonic transducer is not reproducible and not constant and that the way in which the tip of the horn oscillates, even with energetic insignificant transmission of ultrasonic energy from the horn to the welding device is still dependent on various circumstances, eg, on how strongly the screws are tightened which secure the flange to the welding device. The oscillations of the tip of the horn are also dependent on how the capillary is secured to the horn as can be taken, for example, from patent documents US 5 180 093 and US 5 368 216.

The object of the invention is to propose an ultrasonic transducer with a flange for mounting on an ultrasonic welding device with which the above-mentioned disadvantages are overcome. A further object is to form the horn of the ultrasonic transducer in such a way that its tip carries out controllable oscillations even on the application of high frequency ultrasonic waves.

The named objects are resolved in accordance with the invention by means of the features of claims 1 and 6.

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BRIEF DESCRIPTION OF THE INVENTION

According to the invention, the object is resolved in that the linear dimensions of the flange are aptly proportioned so that standing radial ultrasonic waves develop in the flange which have at least one node. Such a node is described hereinafter as a radial node. The drill holes for mounting the flange on the ultrasonic welding device by means of screws, eg, on a Wire Bonder, are arranged in this node. The surface immediately surrounding the drill holes which is in direct contact with the ultrasonic welding

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device therefore hardly resonates and no or only minimum transmission of ultrasonic energy takes place from the horn to the ultrasonic welding device via the flange. The ultrasonic transducer and the ultrasonic welding device are therefore mechanically completely decoupled. The remaining ultrasonic energy which is transmitted from the horn to the ultrasonic welding device is negligibly small.

5 An embodiment of the invention is explained in more detail hereinafter with reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

It is shown, in:

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| | Fig. 1a | an ultrasonic transducer with a flange in plan view, |
| 10 | Fig. 1b, c | the amplitude of the standing ultrasonic waves which develop in the
horn of the ultrasonic transducer or in the flange on excitement by a
predetermined resonance frequency, |
| | Fig. 2a-c, 3a, b,
4a, b, 5a, b, | results of mathematical calculations, |
| 15 | Fig. 6 | the tip of the horn of the ultrasonic transducer, |
| | Fig. 7 | a fixture, |
| | Fig. 8 | a frequency spectrum, and |
| | Fig. 9 | a way of fastening the flange to an ultrasonic welding device. |

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DETAILED DESCRIPTION OF THE INVENTION

Fig. 1a shows the plan view of an ultrasonic transducer 1 with an oblong horn 2 and an ultrasonic converter 3 which applies ultrasonic waves to the horn 2. In the lengthwise direction of the horn 2, standing ultrasonic waves develop on excitement of the horn 2 with a resonance frequency by the ultrasonic converter 3: The ultrasonic waves have so-called longitudinal nodes 5 (Fig. 1b) as well as antinodes 6 whose position and number depend on the length L_1 of the horn 2, the sound velocity of the ultrasonic waves in the horn material 2 and on the frequency of the ultrasonic waves generated by the ultrasonic converter 3.

30 Fig. 1b shows the amplitude A of the ultrasonic waves along the horn 2 on excitement of the horn 2 by the ultrasonic converter 3 with a predetermined resonance frequency f_R . The resonance frequency f_R is, eg, with around 124 kHz, selected so high that five longitudinal nodes 5 develop along the horn 2. The flange 4 (Fig. 1a) is arranged on the horn 2 at the location of the second node 5 of the ultrasonic waves. The flange 4 and the horn 2 are manufactured as one part. The flange 4 is formed symmetrically in
35 relation to the longitudinal axis of the horn 2 and has a drill hole 7 or 8 on both sides of the horn 2 so that the ultrasonic transducer 1 can be mounted on an ultrasonic welding device 9, eg, on a Wire Bonder by means of screws. Radially aligned ultrasonic waves expand in the flange 4. The length L_2 of the

flange 4 is now dimensioned in accordance with the invention in such a way that, on application of the resonance frequency f_R to the horn 2, standing ultrasonic waves also develop in the flange 4 which have at least one node 10 (Fig. 1c). These nodes 10 are called radial nodes. The drill holes 7 and 8 are arranged in these nodes 10. The direction of oscillation of the ultrasonic waves in the horn 2 and in the flange 4 is presented with arrows 11 or 12. With longitudinal oscillation we mean an oscillation extending in the lengthwise direction of the horn 2, with radial oscillation we mean an oscillation extending transversely to the longitudinal axis of the horn 2. The length L_2 is measured from the axis of symmetry 13 of the horn 2 up to the tip of the flange 4.

It is of advantage, as shown in Fig. 1a, when the flange 4 is formed somewhat thicker in the area of the drill holes 7, 8. Thereby, only the surfaces 14 of the flange 4 which immediately surround the drill holes 7, 8 come in contact with the ultrasonic welding device 9. In ultrasonic terms, the ultrasonic transducer 1 is completely decoupled from the ultrasonic welding device 9 and therefore can freely oscillate practically without friction on the ultrasonic welding device 9. A solution is also possible with which the flange 4 is realized with a constant thickness D. In this case, the contact surface of the ultrasonic welding device 9 touching the flange 4 should be correspondingly small.

Fig. 2a-c and later Fig. 4a and b show results of mathematical calculations whereby lines 16 are drawn whose distance is proportional to the local oscillation amplitude of the ultrasonic waves. A smaller distance means that the corresponding area oscillates comparatively strongly while a larger distance means that the corresponding area oscillates comparatively little or is even completely still.

Fig. 2a shows a conventional type flange 4 mounted in one of the longitudinal nodes 5 of the horn 2, ie, a flange with relatively short length L_2 , which can oscillate freely whereby the horn 2 is envisaged as a horn for a Wire Bonder. The conventional flange 4 has a length $L_2 = 9$ mm. For reasons of symmetry, only the side of the flange 4 which contains the drill hole 8 on the right in relation to the axis of symmetry 13 of the horn 2 is drawn. The horn 2 is excited with the predetermined resonance frequency f_R from the ultrasonic converter 3 (Fig. 1a) so that longitudinal standing ultrasonic waves develop in the lengthwise direction. Because its length L_2 is too short, no radial node can develop in the flange 4 with the frequency f_R . Fig. 2b shows the same flange 4, for which a mathematical point P is fixed in the centre of drill hole 8 (Fig. 1a). From Fig. 2a and b it can be seen, that the oscillating behaviour of the conventional flange 4 is strongly dependent on whether the flange 4 can oscillate freely or whether it is fixed at point P. In practice, the position of point P varies as a result of unavoidable tolerances which has the result that the actual position at which the screws press the flange 4 against the ultrasonic welding device 9 and the actual force which they thereby exert locally on the flange 4, influence the oscillations of the tip 15 of the horn 2 to an undesirable extent. The oscillations of the tip 15 of the horn 2 are thereby not reproducible. As forces occur in the point P, a part of the ultrasonic energy is also lost through friction at the attachment point P.

Fig. 2c shows a flange 4' in accordance with the invention, ie, a flange with relatively large length L_2' ,

which can oscillate freely. The example calculation resulted in the optimum length $L_2' = 16$ mm. When the horn 2 is excited by the selected resonance frequency f_R , radial ultrasonic waves develop in the flange 4' which also have a node 10. The node 10 is located at a distance $d' = 5$ mm from the axis of symmetry 13 of the horn 2. When the drill holes 7, 8 for attachment of the ultrasonic transducer 1 are mounted in this node 10, the oscillating behaviour of the horn 2 does not change when the ultrasonic transducer 1 is mounted on the ultrasonic welding device 9. The horn 2 and the ultrasonic welding device 9 can therefore be completely mechanically decoupled so that the oscillations of the tip 15 of the horn 2 are no longer dependent on whether and with which force the flange 4' is secured to the ultrasonic welding device 9.

- 10 Fig. 3a shows a further disadvantage of the conventional flange 4. When the flange 4 is fixed at point P, it bends on the application of ultrasonic waves to the horn 2. As a comparison, Fig. 3b presents the freely oscillating conventional flange 4 which does not bend. The extended edge lines show the resting position of the horn 2 or flange 4. The dashed edge line shows the horn 2 or the flange 4 in the state of maximum oscillation amplitude. The deflection of the tip of the flange 4 is in phase with the deflection of the horn 2 at node 5 in radial direction. These bending oscillations lead, on the one hand, to the flange 4 vibrating on the ultrasonic welding device 9 and, on the other hand, to undesirable bending oscillations occurring in the horn 2 because of the reaction. The oscillations of the tip 15 of the horn 2 are not reproducible as the strength of the bending oscillations of the horn 2 can be dependent on the force with which the screws press the flange 4 against the ultrasonic welding device 9. With the flange 4' in accordance with the invention, no bending occurs at point P.

The simulations show that the resonance frequency f_R and therefore the position of the longitudinal node 5 (Fig. 1b) vary slightly as a function of the length L_2' of the flange 4' in accordance with the invention. It is therefore advisable to adjust the position of the flange 4' by the position shift of the node 5 and in this way to iteratively optimise the position and length L_2' .

- 25 In order to be able to retrofit existing Wire Bonders with an ultrasonic transducer 1 with such a flange without having to carry out mechanical changes to the Wire Bonder, the position of drill holes 7, 8 must not be altered, ie, their distance d'' from the axis of symmetry 13 of the horn 2 is firmly preset. The length L_2'' of the flange is therefore, according to the invention, to be dimensioned in such a way that node 10 develops as far as possible at the location of the drill hole 7 or 8 under the prerequisite that the flange can oscillate freely. Fig. 4a shows another freely oscillating flange 4'', in which a radial node 10 develops in the immediate vicinity of drill hole 7. The example calculation resulted in an optimum length $L_2'' = 18$ mm for the distance $d'' = 7$ mm of drill holes 7, 8 from the axis of symmetry 13 of the horn 2. Fig. 4b shows the other flange 4'', for which a mathematical point P is now fixed at the preset location of drill hole 7. From Fig. 4a and 4b it can be seen that the solution with the length $L_2'' = 18$ mm is a practicable solution with which the oscillating behaviour of the flange 4'' is also hardly dependent on whether the flange 4'' can oscillate freely or whether it is fixed at point P.

Fig. 5a and 5b show that the other flange 4'' fixed at point P and secured according to the invention (Fig. 5a) does not bend on application of ultrasonic waves to the horn 2 and that it oscillates very similarly to the freely oscillating flange 4'' (Fig. 5b). The deflection of the tip of the flange 4 here is in phase opposition to the deflection of the horn 2 at node 5 in radial direction.

5 The invention can also be applied for other types of horn, eg, for a horn formed symmetrically in relation to its longitudinal axis such as is, for example, shown in the Patent Document US 5 469 011. The flange 4' in accordance with the invention can also be arranged on the ultrasonic converter 3 instead of on the horn 2. It must be noted thereby, that in the widest sense, under the term horn a fixture for the ultrasonic generating elements (eg, of piezoelectric or magnetostrictive materials) is also meant, ie, in
10 this case ultrasonic converter 3 and horn 2 (Fig. 1a) form one single part.

In the exemplary embodiment as shown so far the flange 4 is mounted by means of screws on the ultrasonic welding device 9. Therefore the flange 4 has drill holes 7 and 8 which are arranged at the position of the nodes 10. Principally also other ways of fastening are possible wherein the flange does not have drill holes but is fastened to the ultrasonic welding device 9 by means of clamping means
15 attacking at the nodes 10. With such a solution the flange 4 preferably comprises a nut into which the fastening means and/or the counterpart of the ultrasonic welding device 9 engages. Fig. 9 discloses such an example. A screw 28 engaging into the nut 27 serves as clamping means, the screw exerting pressure on the flange 4 at the position of the node 10.

Fig. 6 shows the tip of the horn 2 in detail. The horn is formed symmetrically in relation to its
20 longitudinal axis, therefore possessing the axis of symmetry 13. The horn 2 contains a drill hole 17 for acceptance of a capillary 18. The drill hole 17 is connected to a slit 19 running in the lengthwise direction of the horn 2. A further drill hole 20 penetrating the slit 19 is arranged transversely to the axis of symmetry 13 of the horn 2. The drill hole 20 ends on both sides in cavities 21 in the horn 2. Both cavities 21 are also formed symmetrically to one another. The cavities 21 at least partly accept the head
25 of a screw 22 inserted into the drill hole 20 or of a nut 23 in combination with the screw 22. The head of the screw 22, the length of the screw 22 and the size of the nut 23 are adapted to each other in such a way that the mass of the head of the screw 22 and the mass of the nut 23 together with the mass of the end of the screw located outside the nut have almost the same value. This distribution of masses from screw 22 and nut 23 in relation to the axis of symmetry 13 of the horn 2 leads to a symmetrical
30 development of the ultrasonic waves in relation to the longitudinal axis and therefore an optimum movement of the capillary 18. The cavity 21 accepting the nut 23 is so advantageously adapted to the nut 23 in shape and diameter that the nut 23 inserted into the cavity 21 can no longer turn.

Fig. 7 shows a fixture which can be used instead of the screw 22 and the nut 23. The screw 22 with its head is replaced by a screw thread 24 and a second nut 25. This fixture enables a distribution of the
35 masses of the screw thread 24 and the two nuts 23, 25 which is completely symmetrical to the longitudinal axis of the horn 2 in that, one or other of the nuts 23, 25 can be tightened on securing the

capillary. The symmetry of the mass distribution can be checked metrologically in that the electrical impedance Z of the ultrasonic converter 3 is measured as a function of the frequency f of the ultrasonic waves generated by the ultrasonic converter 3. Fig. 8 shows the modulus B of impedance Z of such a spectrum as an extract. This has a spurious resonance 26 on unsymmetrical mass distribution of screw 5 22 and nut 23 or of screw thread 24 and the nuts 23, 25 in the vicinity of the desired resonance frequency f_R of the longitudinal oscillations which belongs to a bend oscillation of the horn 2. The spurious resonance 26 can disturb the longitudinal oscillations of the tip 15 of the horn 2 in that it superimposes transverse oscillations on the longitudinal oscillations. On symmetrical mass distribution, the spurious resonance 26 disappears.



CLAIMS

1. Ultrasonic transducer with a horn and with an ultrasonic converter which applies ultrasonic waves to the horn so that standing ultrasonic waves develop in the lengthwise direction of the horn whereby a flange is arranged on the horn or on the ultrasonic converter at the location of a node of the ultrasonic waves and whereby the flange has such a large length that in the flange, when it can freely oscillate,
5 standing ultrasonic waves develop which also have at least one node.
2. Ultrasonic transducer according to claim 1, whereby the flange is only in contact with the ultrasonic welding device with surfaces which immediately surround its at least one node.
3. Ultrasonic transducer according to claim 1, whereby a drill hole is present in the at least one node
10 in order that the flange can be fastened at the ultrasonic welding device by means of screws.
4. Ultrasonic transducer according to claim 2, whereby a drill hole is present in the at least one node in order that the flange can be fastened at the ultrasonic welding device by means of screws.
5. Ultrasonic transducer according to one of claims 1 to 4 whereby the horn has a drill hole for acceptance of a capillary, whereby the capillary is secured by means of a screw inserted through a
15 further drill hole in combination with a nut and whereby the distribution of the masses of the screw and the nut is symmetrical in relation to the longitudinal axis of the horn.
6. Ultrasonic transducer with a horn whereby the horn has a drill hole for acceptance of a capillary, whereby the capillary is secured by means of a screw inserted through a further drill hole in combination with a nut and whereby the distribution of the masses of the screw and the nut is symmetrical in relation
20 to the longitudinal axis of the horn.